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Outburst flood evolution at Russell Glacier, western Greenland:

effects of a bedrock channel cascade with intermediary lakes

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UNIVERSITY OF LEEDS

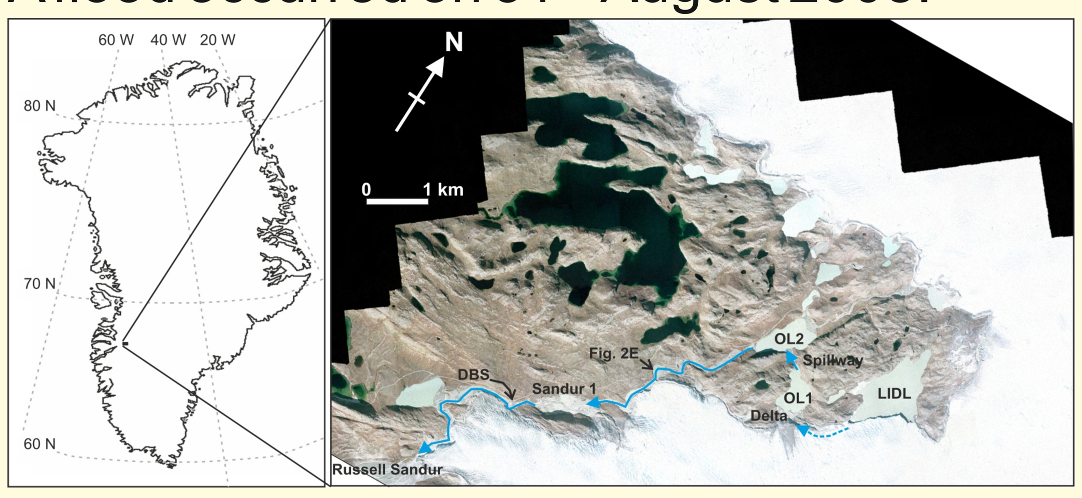
1. INTRODUCTION AND RATIONALE

Quaternary glacial lake outburst floods (GLOFs), which are a type of jökulhlaup, were a key part of deglaciation from the Last Glacial Maximum (LGM). The very largest of these jökulhlaups affected climate via disruption of ocean thermohaline circulation. They were triggered by failure of a glacier ice dam and routed via a cascade of topographic bedrock basins and on occasions through pre-existing intermediary lakes. Quaternary outburst floods produced intense geomorphological impacts through excavation of onshore bedrock canyons and submarine canyons and redistribution of vast amounts of sediment across land and into oceans. Understanding of Quaternary outburst floods is generally restricted by a lack of modern analogues.

The overall aims of this study were to make the first systematic and detailed quantification of the effects of (i) intermediary lakes on the longitudinal and temporal hydraulic evolution of an outburst flood, and (ii) the effects of bedrock channel topography on outburst flood evolution.

2. STUDY SITE

Russell Glacier, western Greenland (Fig. 1). A flood occurred on 31st August 2008.



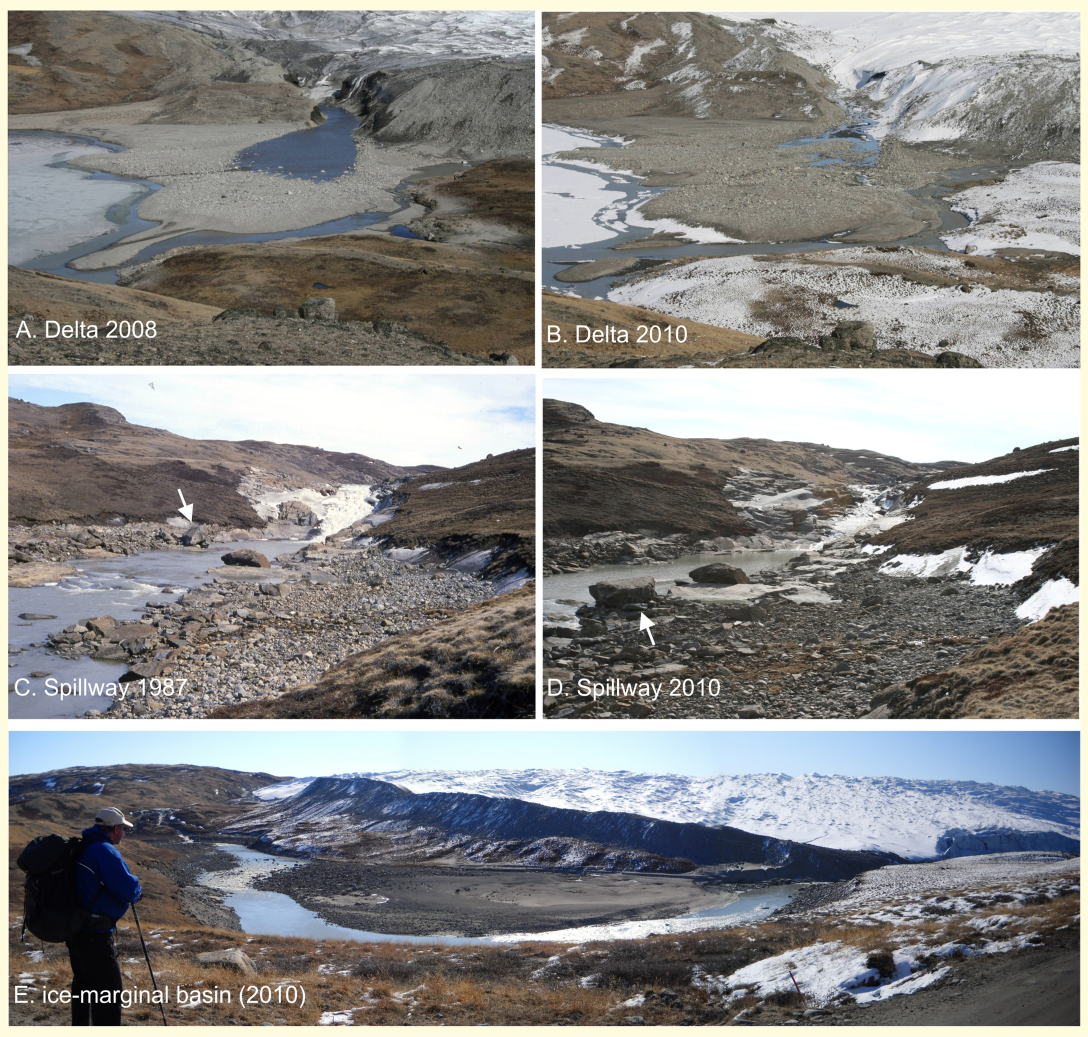


Fig. 2: Erosion and deposition due to the 2008 flood

Large ice-dammed lake at Russell Glacier, after draining.

Fig. 3. Quantification of flood routeway channel.

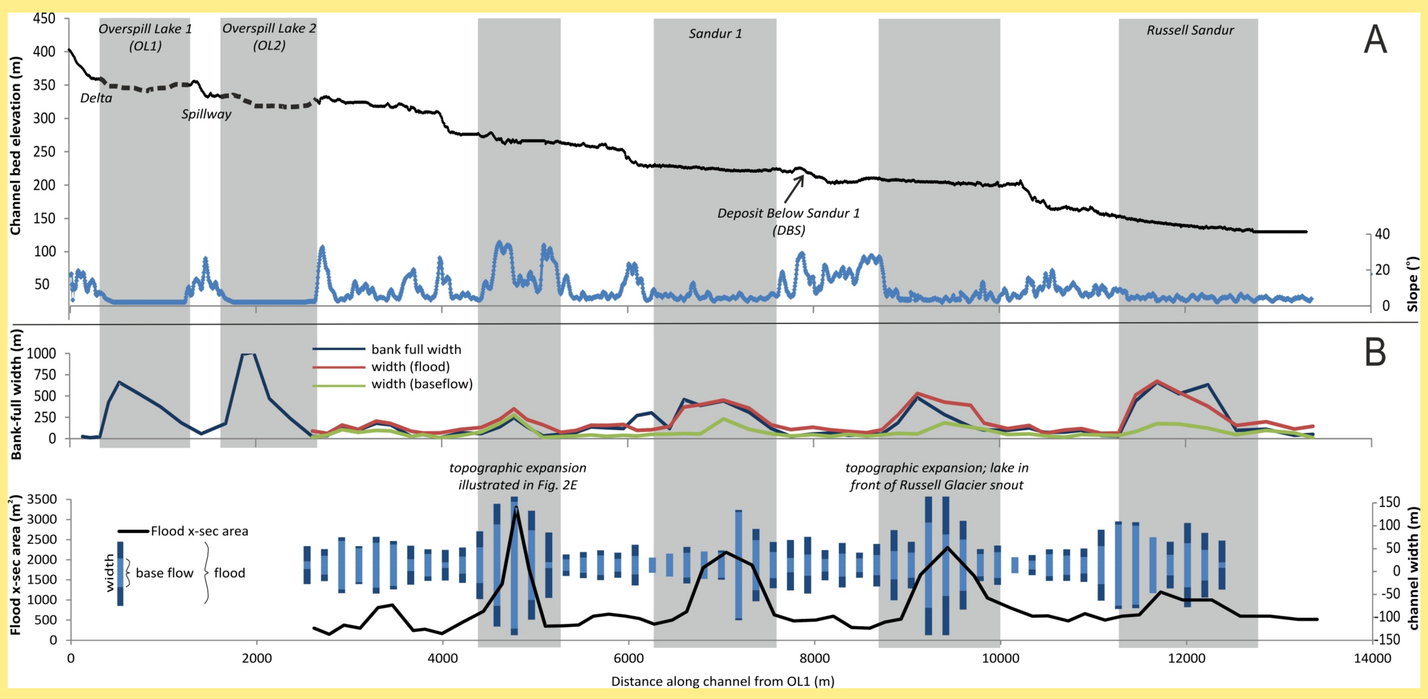
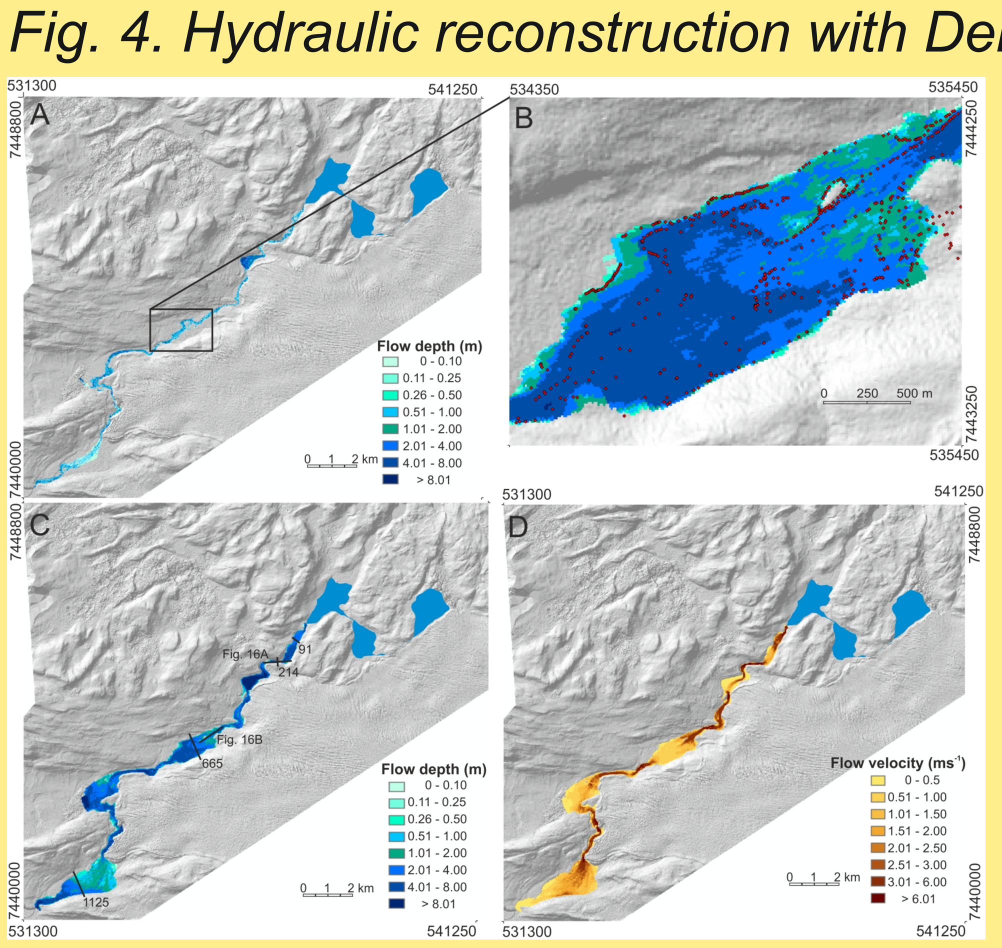


Fig. 4. Hydraulic reconstruction with Delft3d model.



The model was driven by a flood hydrograph gained from measured lake level drawdown, and a 5 m grid digital elevation model.

The model attained very good agreement with field-surveyed wash limits (4B).

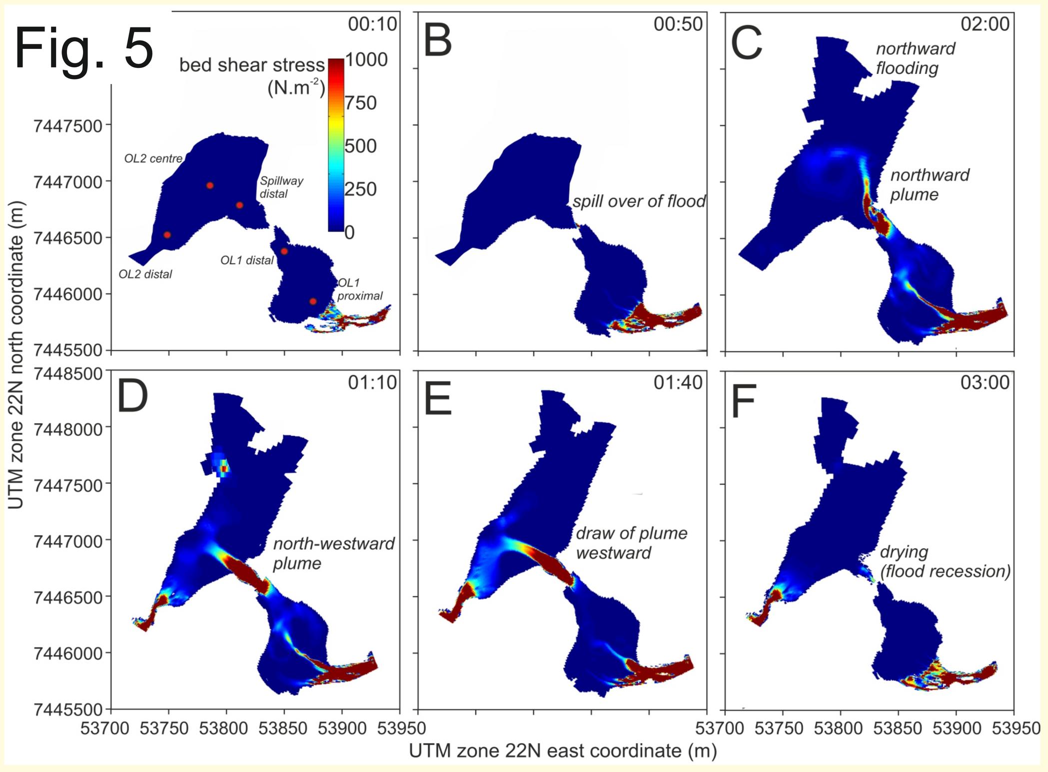
The model output included spatially-varied (gridded) flow depth, flow velocity and other hydraulic parameters at 10 min. intervals.

Gridded hydraulic variables were analysed using a bespoke program to calculate rate of rise to peak and duration of peak per cross section; see Figure 6.

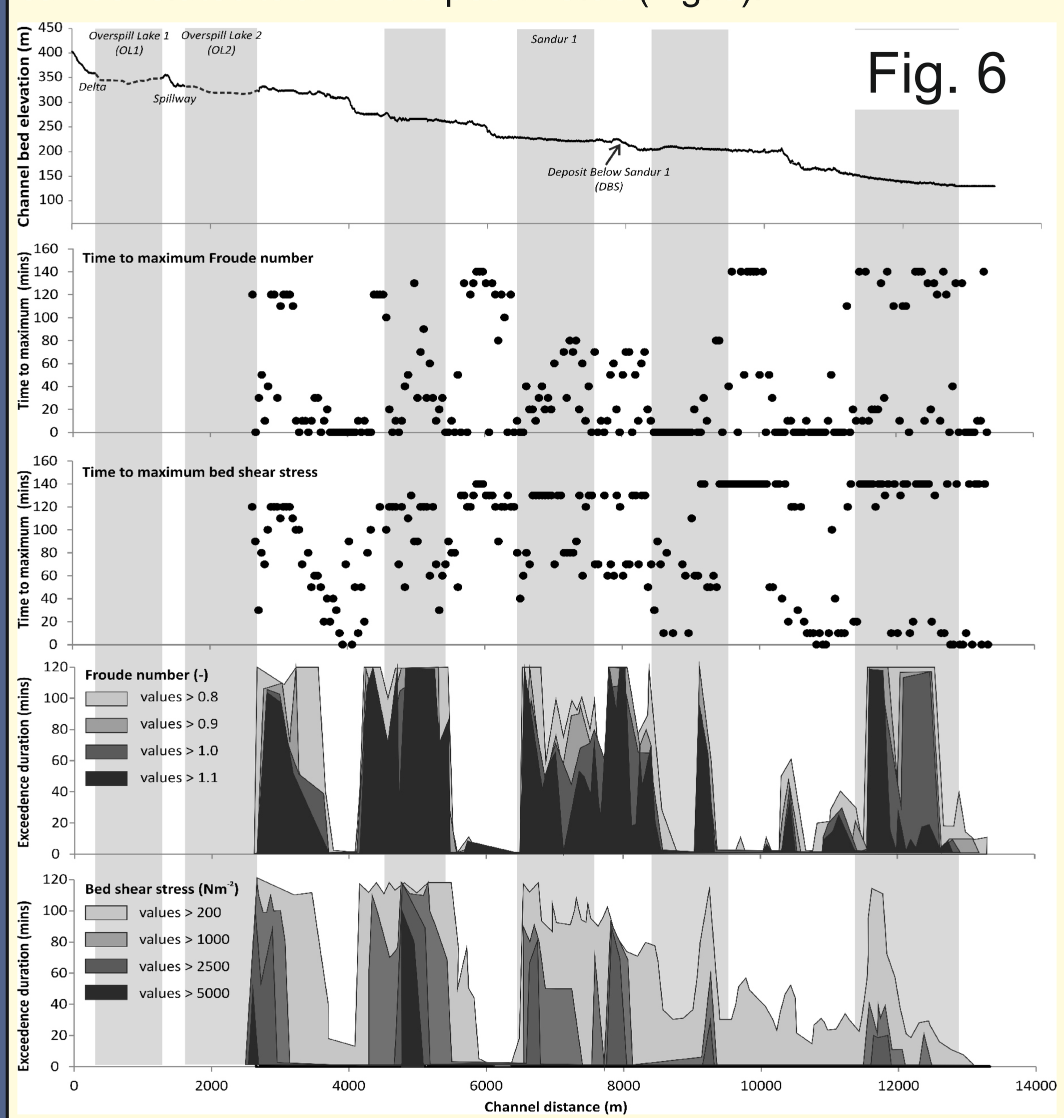
5. MAJOR FINDINGS

(i) Flood propagation dramatically attenuates whilst basin filling proceeds to the outlet level (Fig. 5)
(ii) Considerable water recirculation and hence energy dissipation occurs during the rising stage of the flood,
(iii) Overtopping of the outlet occurs; although basin inflow may still be greater than basin outflow, and outflow discharge is moderated in peak discharge but sustained in duration.

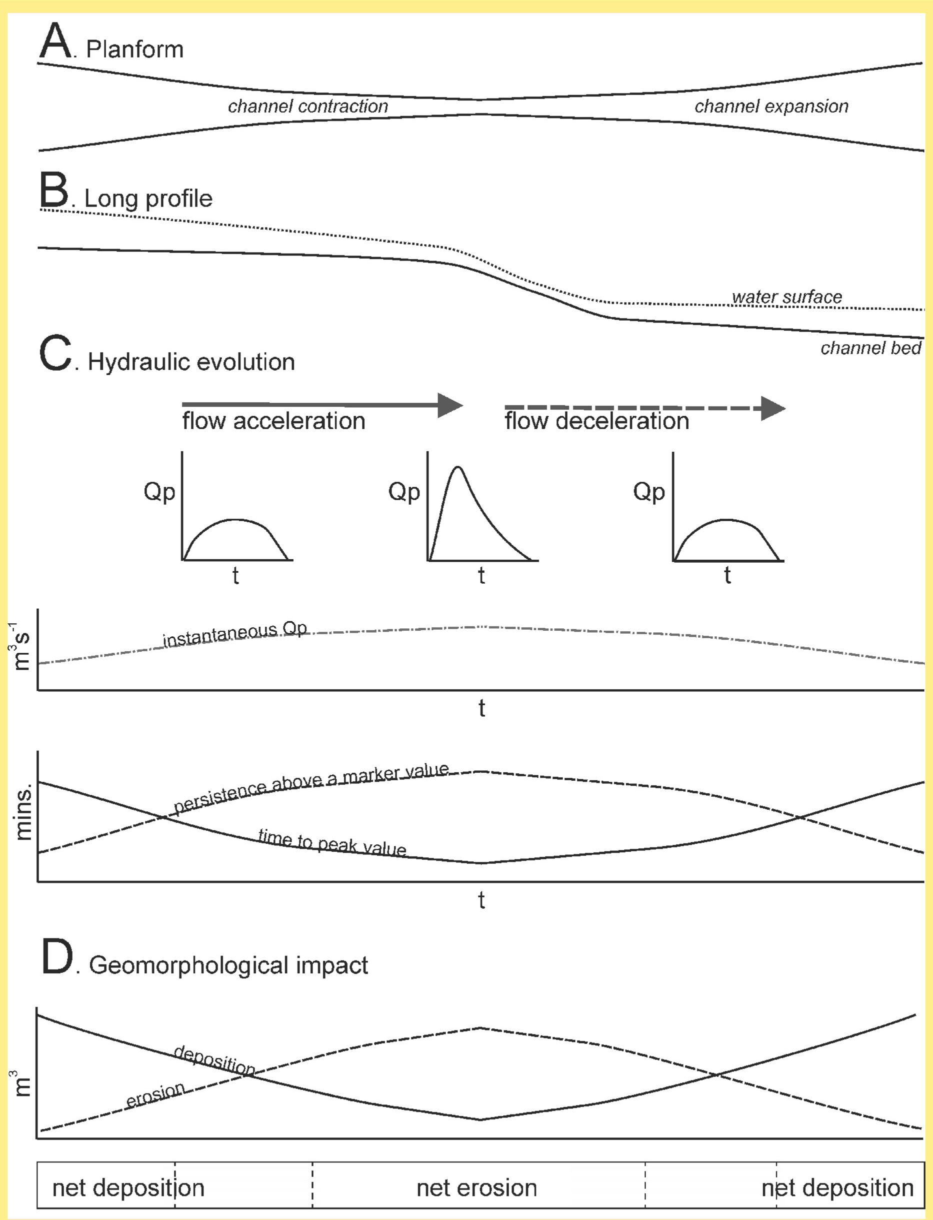
Fig. 5



(iv) Bedrock channel topography can produce kinematic waves within an outburst flood via hydraulic ponding and these waves most likely account for hydropeaking (Fig. 6).
(v) Evolution of bed shear stress can be decoupled from the evolution of flow depth due to the transition from channelized to sheet-like flow.
(vi) Flood hydrograph shape evolves in bedrock channels with increasing as well as decreasing magnitudes of peak discharge, faster as well as slower rates of rise to peak discharge and longer as well as shorter duration of peak discharge with distance down stream.
(vii) Net erosion along a channel reach can be related to hydraulic persistence above a marker value and net deposition can be related to a 'time to peak' value (Fig. 6).



6. CONCEPTUAL MODEL



7. WIDER IMPLICATIONS

The Quaternary record of bedrock channelled outburst floods may be even more widespread than hitherto recognised, due to the fact that landforms and sediments of outburst floods can be exceptionally disparate, even from a single event.

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REFERENCES AND REPRINTS

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